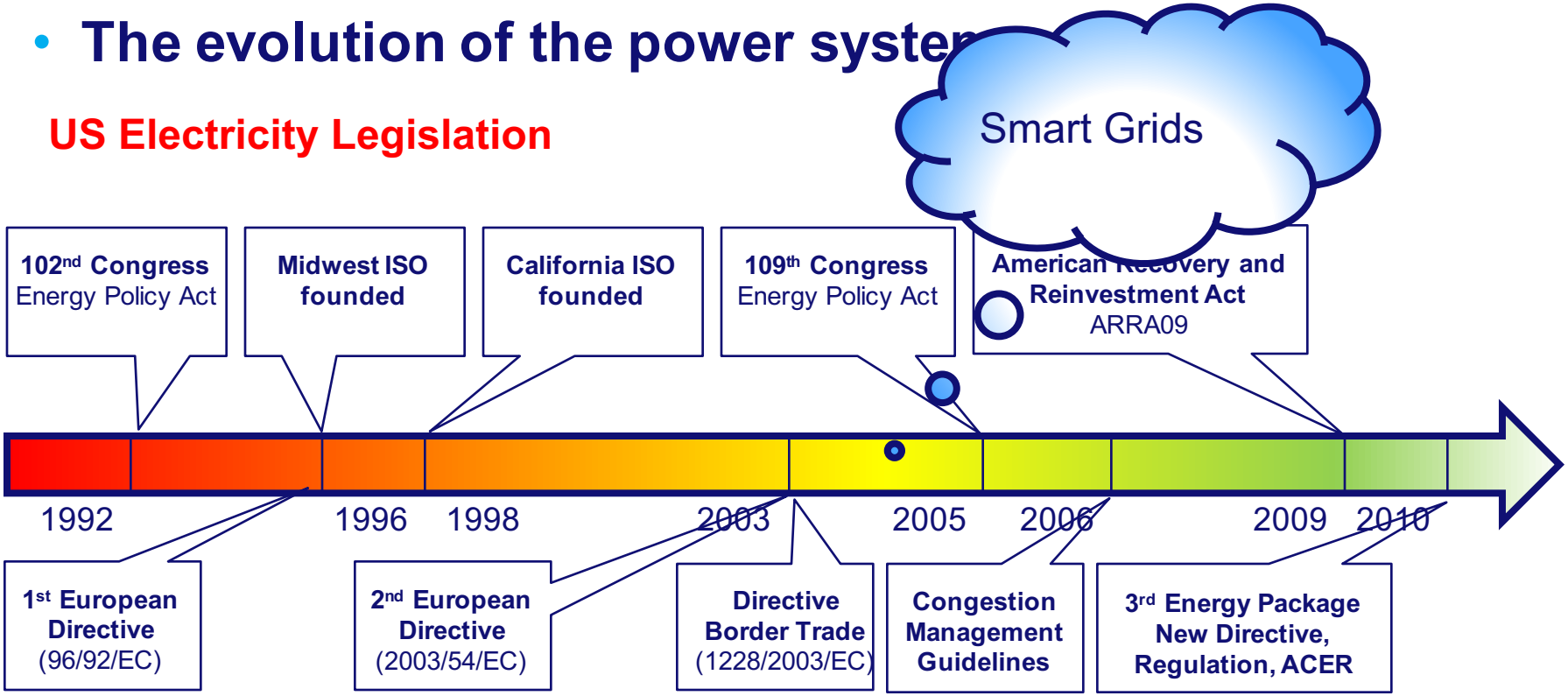
Outline

- European Power System context
- RES & Smart Grids
- Highlighted projects
- Conclusion & Discussion

European Power System context

- **The evolution of the power syste**

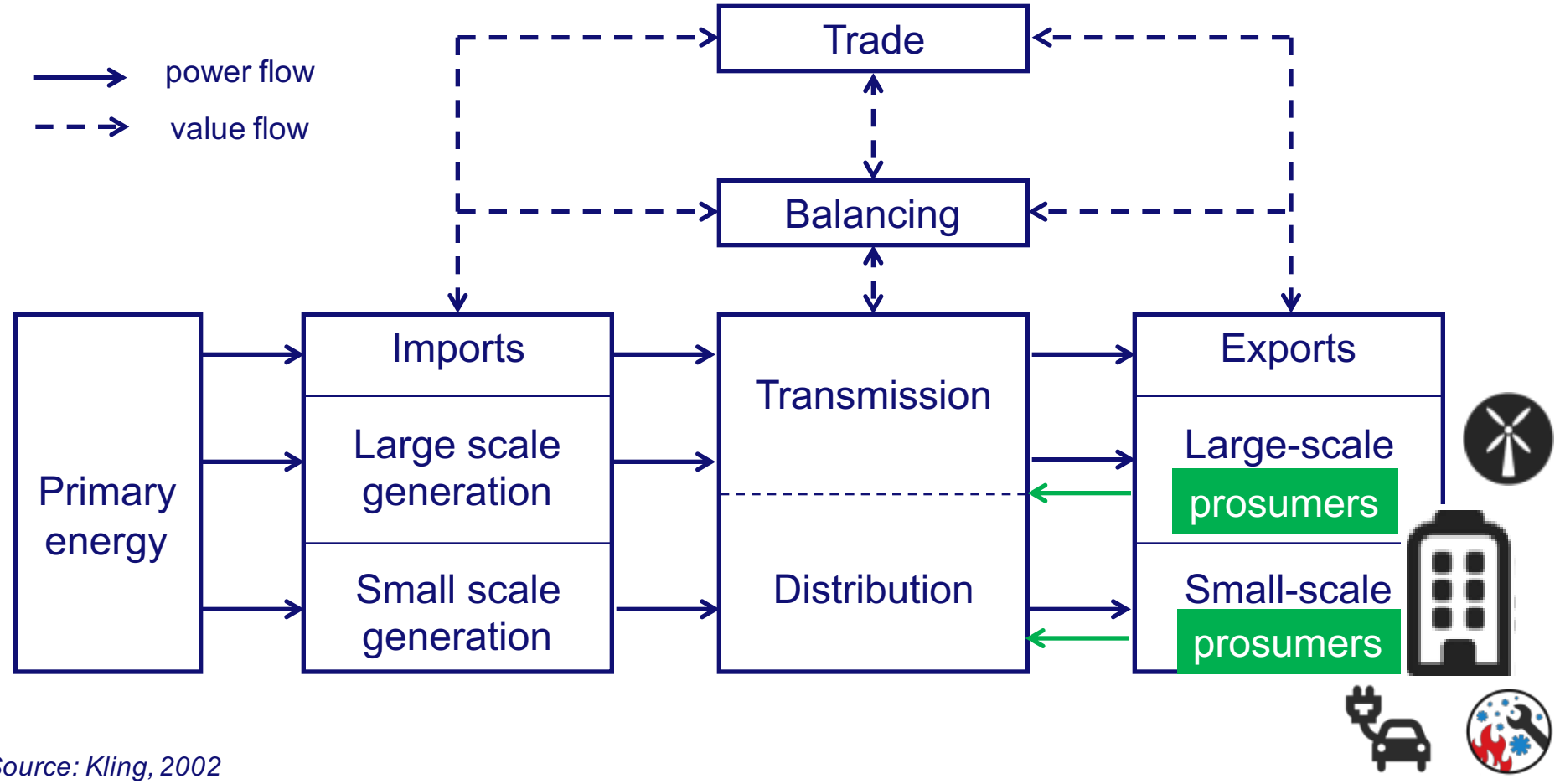
US Electricity Legislation



European Electricity Legislation

S. M. Amin, "Balancing market priorities with security issues," *IEEE Power and Energy Magazine*, vol. 2, no. 4, pp. 30-38, 2004.

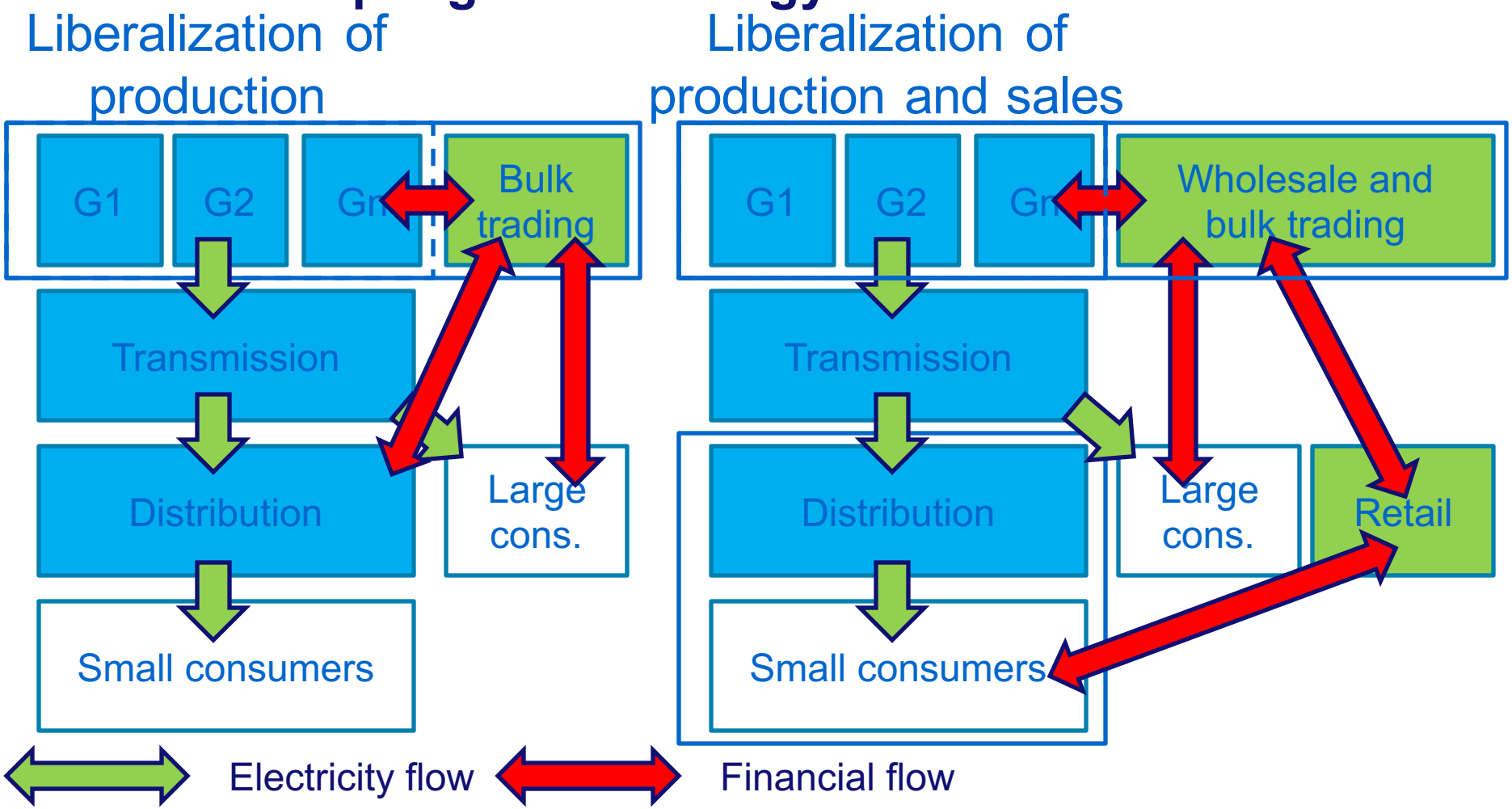
European Power System context



Source: Kling, 2002

European Power System context

Further decoupling of technology and economic value chain



European Power System context

- **RES can be integrated in the liberalized electricity market in three ways:**

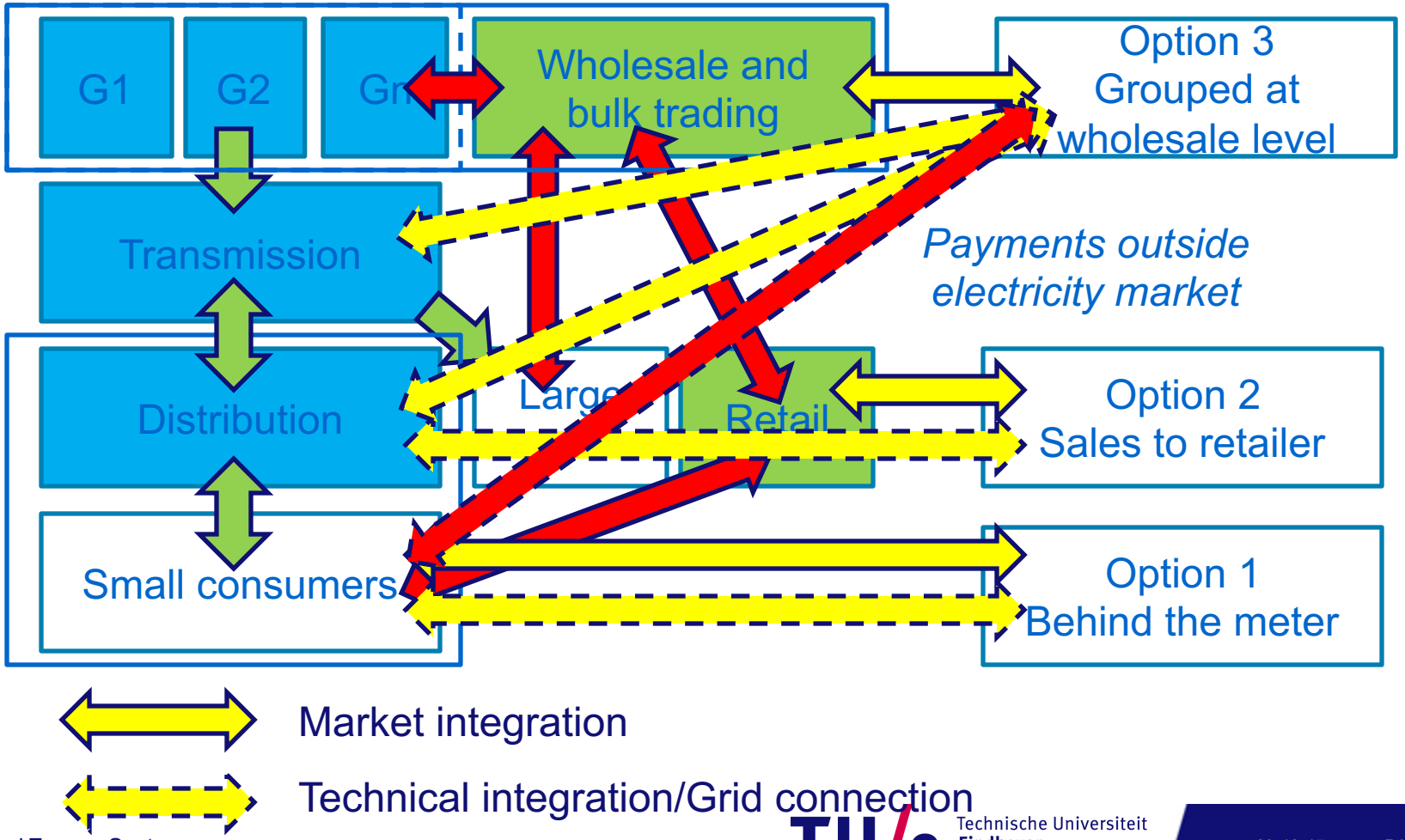
1. Behind the grid connection/electricity meter of a small consumer to reduce amount of electricity bought elsewhere (of course no energy saving)

2. With a separate connection and meter, electricity is sold to retail company normally at fixed price

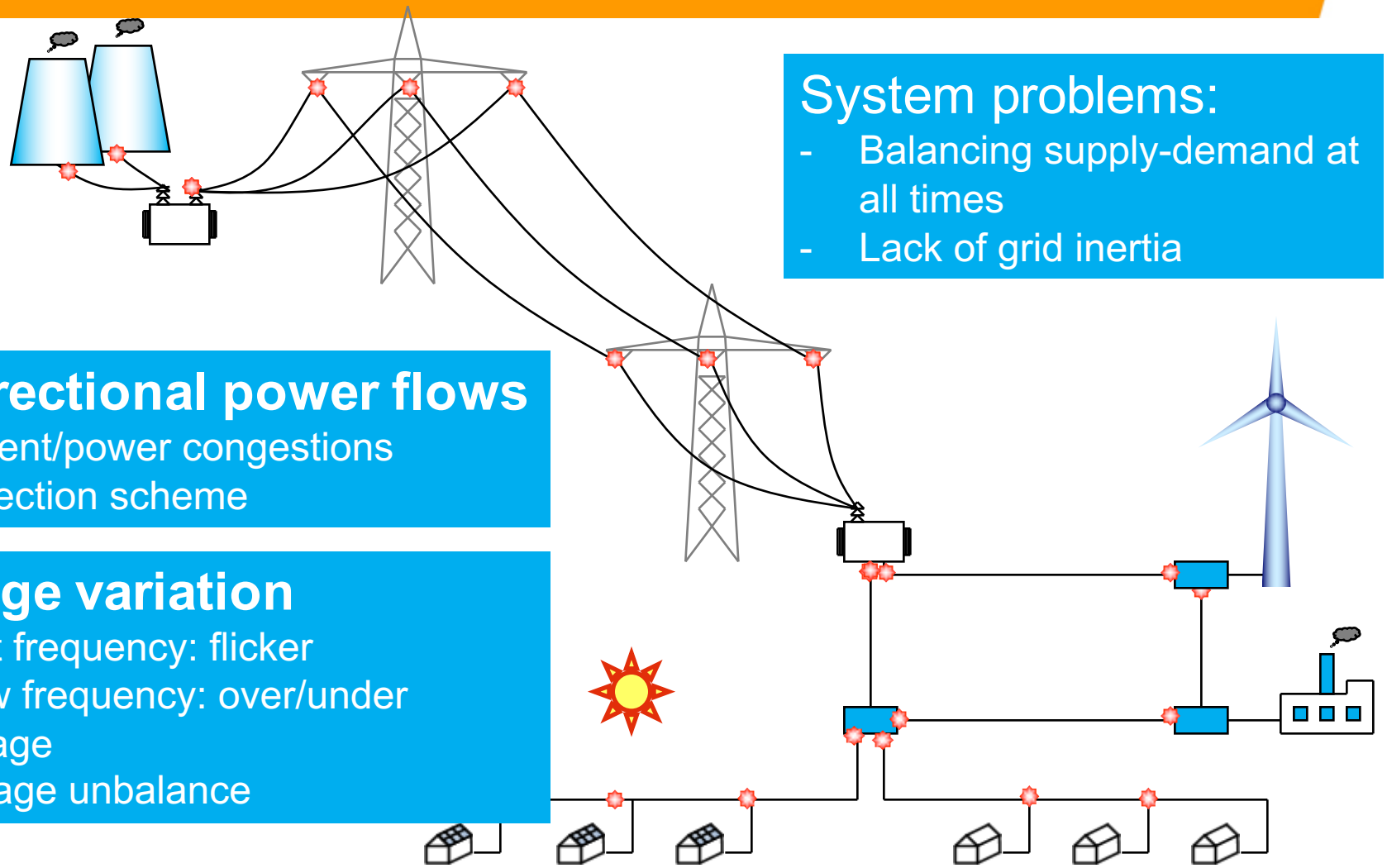
3. Combined in a large (virtual or physical) group; electricity sold at wholesale level, sometimes but not necessarily at fixed price (*in case of virtual group outer market payments from wholesaler to owner*)

European Power System context

Decoupling of technology and value chain for RES



RES & Smart Grids



System problems:

- Balancing supply-demand at all times
- Lack of grid inertia

Bi-directional power flows

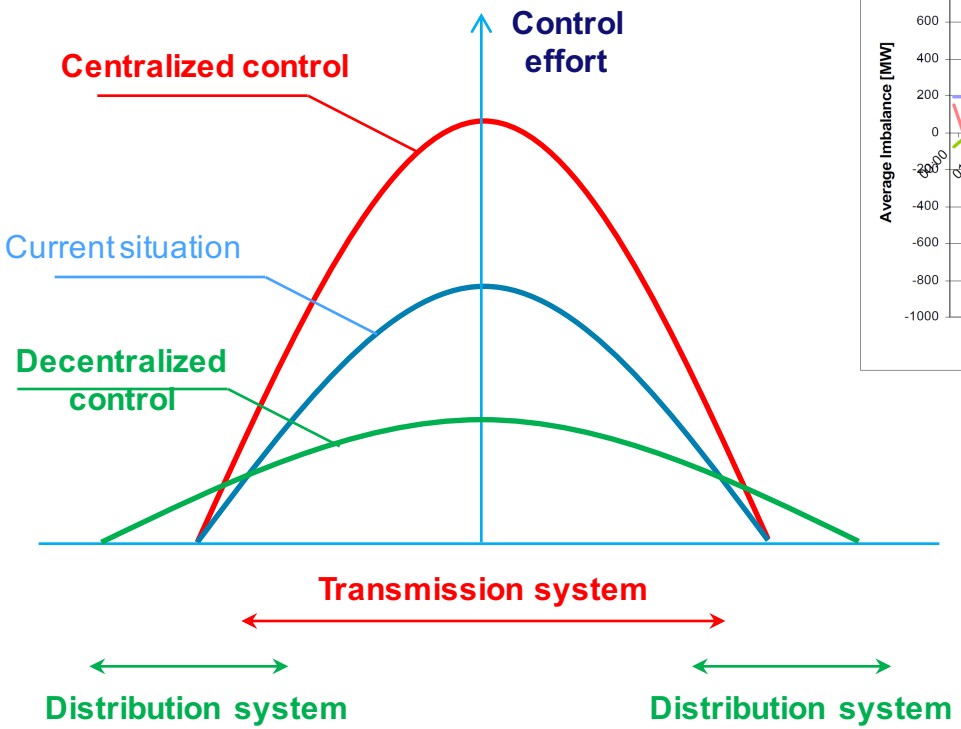
- Current/power congestions
- Protection scheme

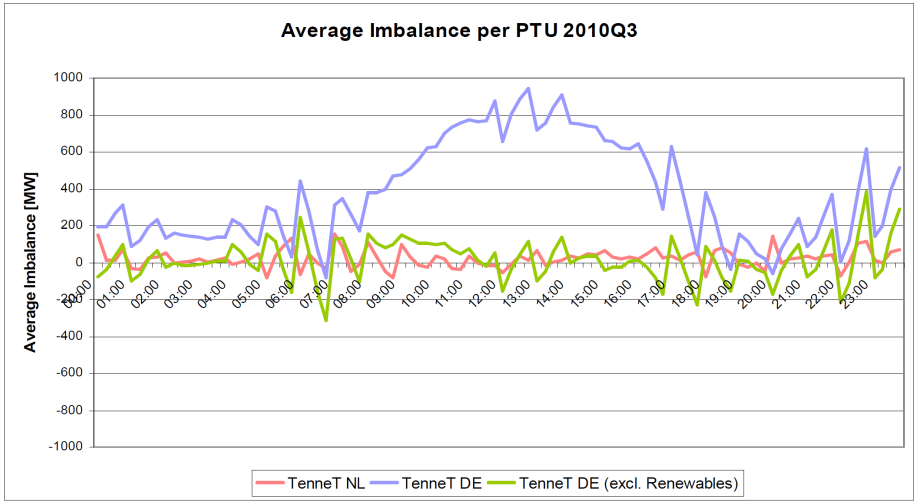
Voltage variation

- Fast frequency: flicker
- Slow frequency: over/under voltage
- Voltage unbalance

RES & Smart Grids

- **Need for…**

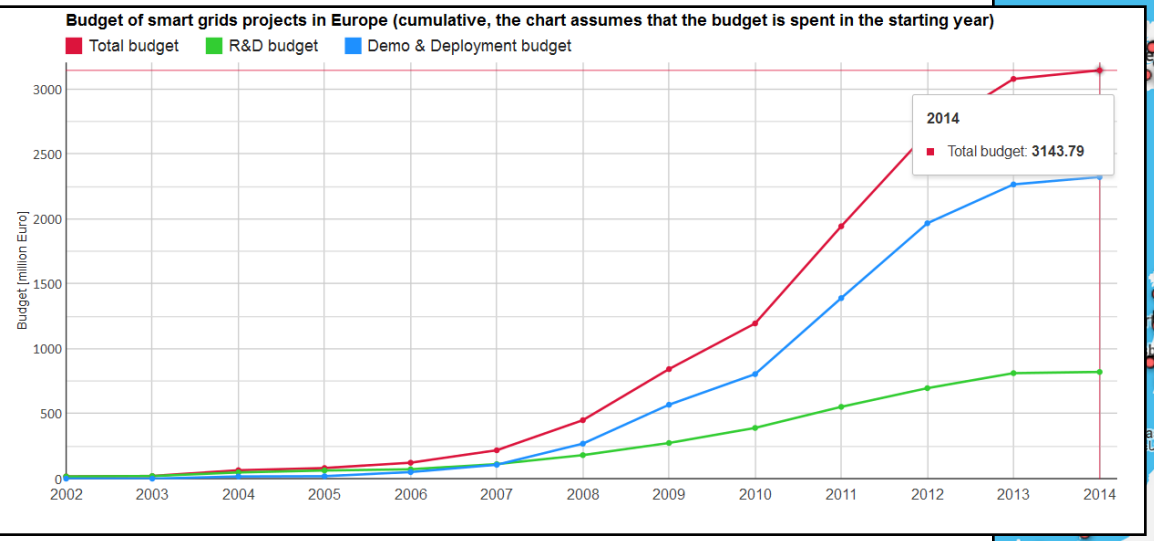


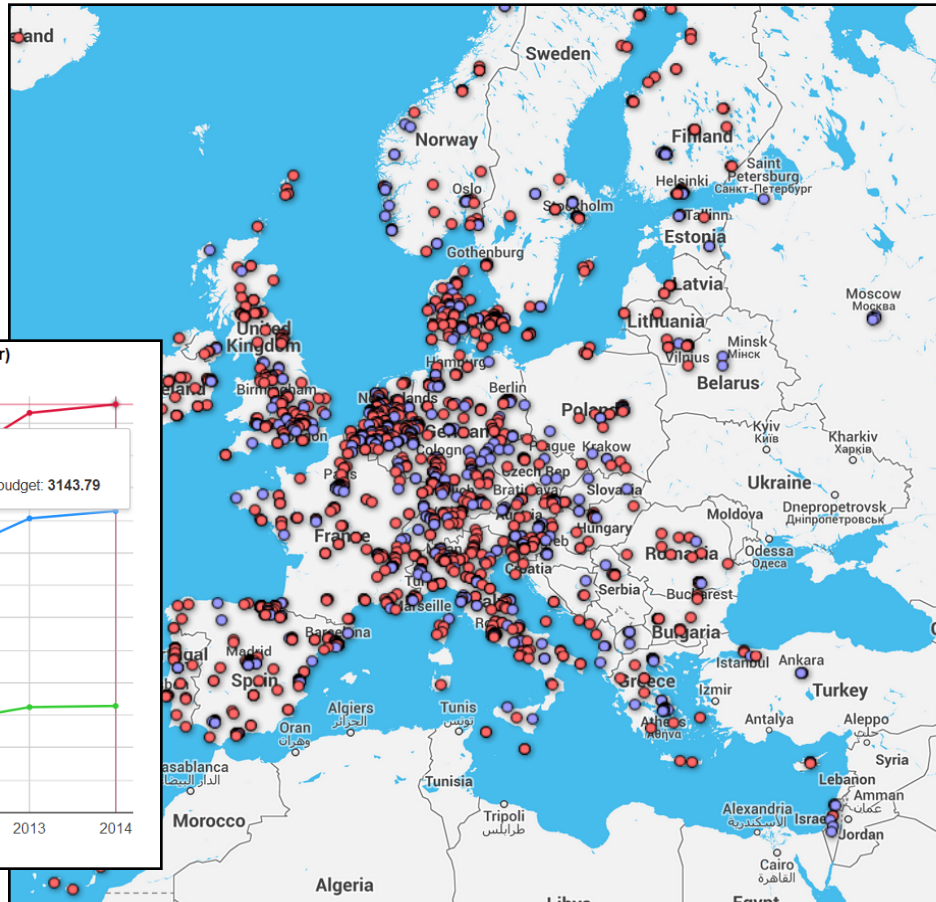


RES & Smart Grids

❑ Development of Smart Grids in Europe

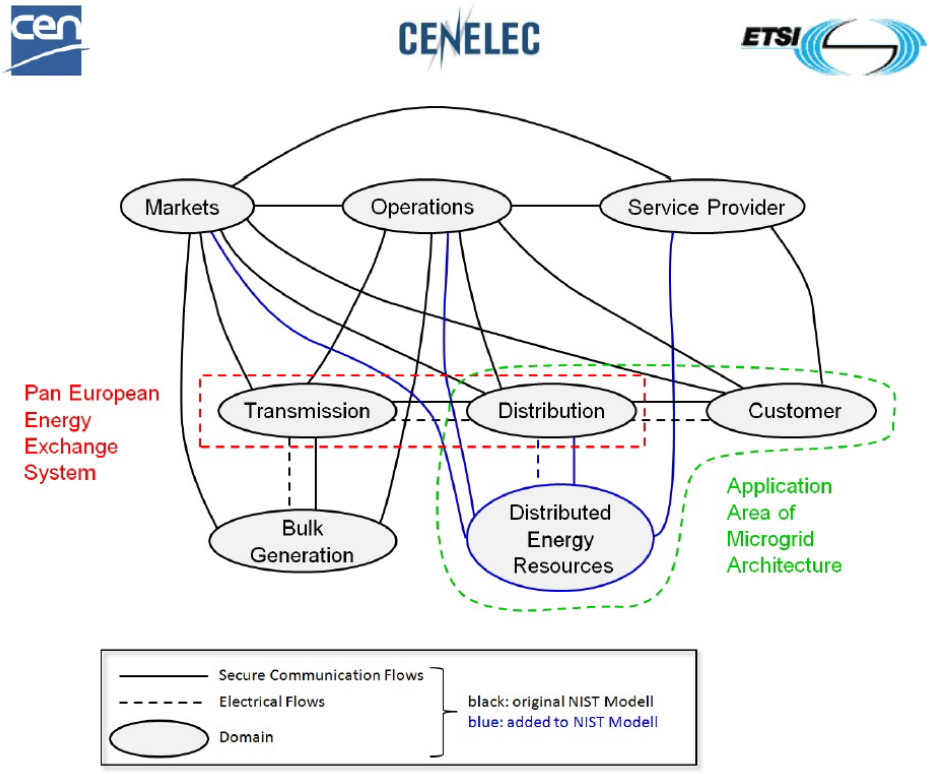
- Smart grid projects outlook 2014 (http://ses.jrc.ec.europa.eu/smart-grids-observatory):
  - 459 smart grid projects from 2002;
  - €3.15 billion investment;
  - SG European Technology Platform
  - SGs Task Forces





RES & Smart Grids

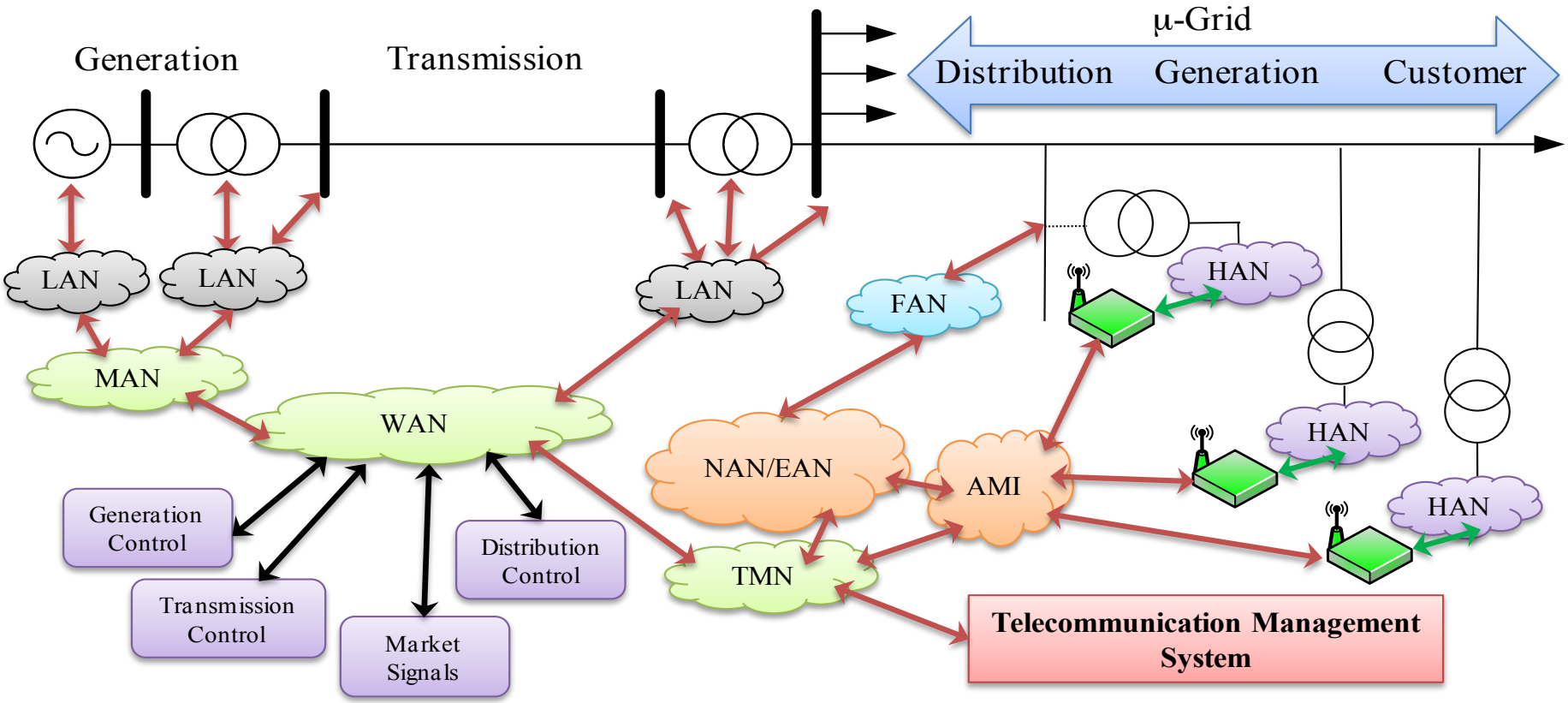
- **No common definition of Smart Grids, but…**
- **Smart Grid Framework**
  - National Institute of Standards and Technology (NIST): "Framework" ver 1.0 and 2.0.
  - CEN-SENELEC-ETSI adopted and extended the "Framework" for EU context.



CEN-CENELEC-ETSI. Smart Grid Reference Architecture. Smart Grid Coordination Group, 2012.

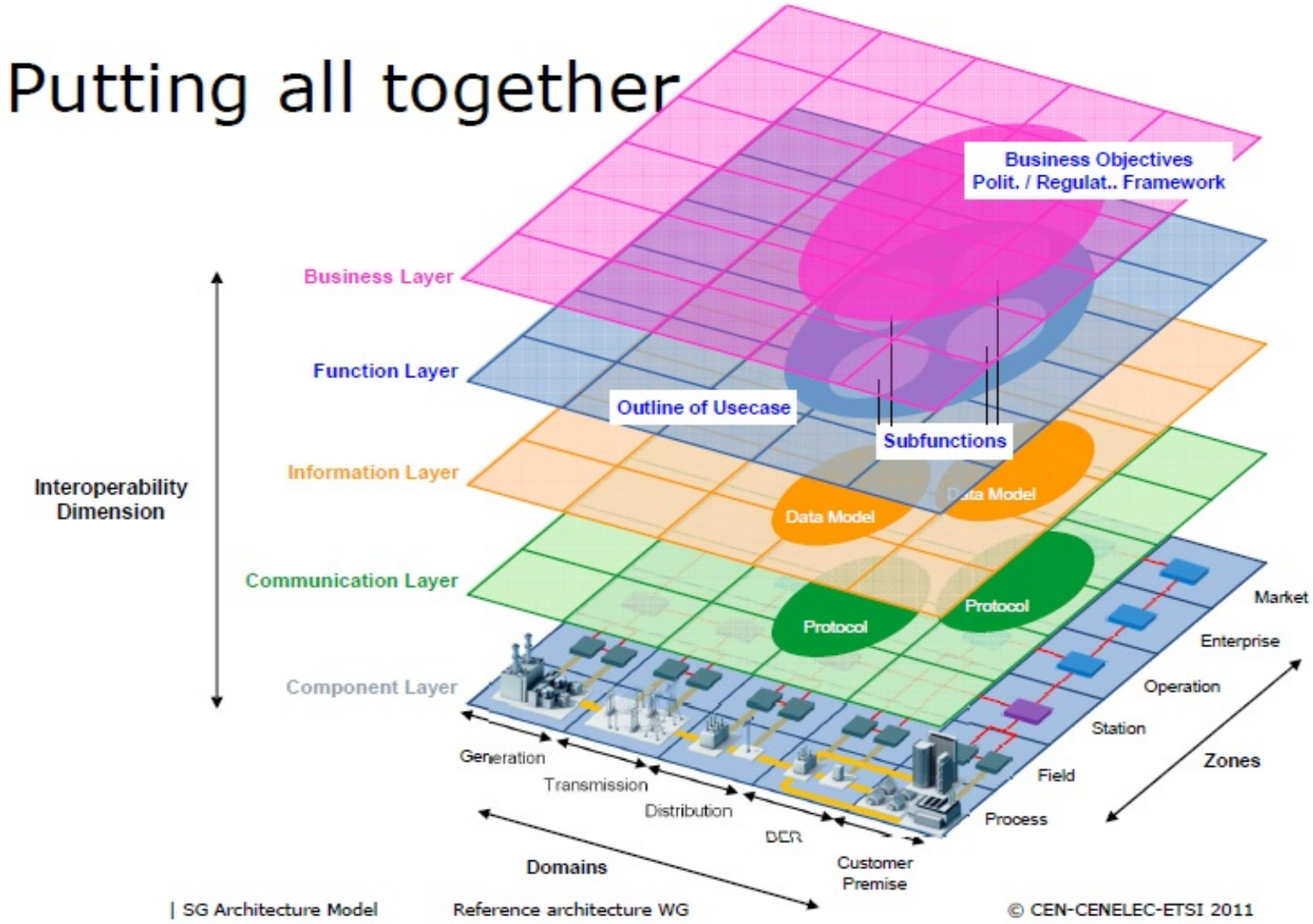
RES & Smart Grids

The Smart Grid Context: everything is connected



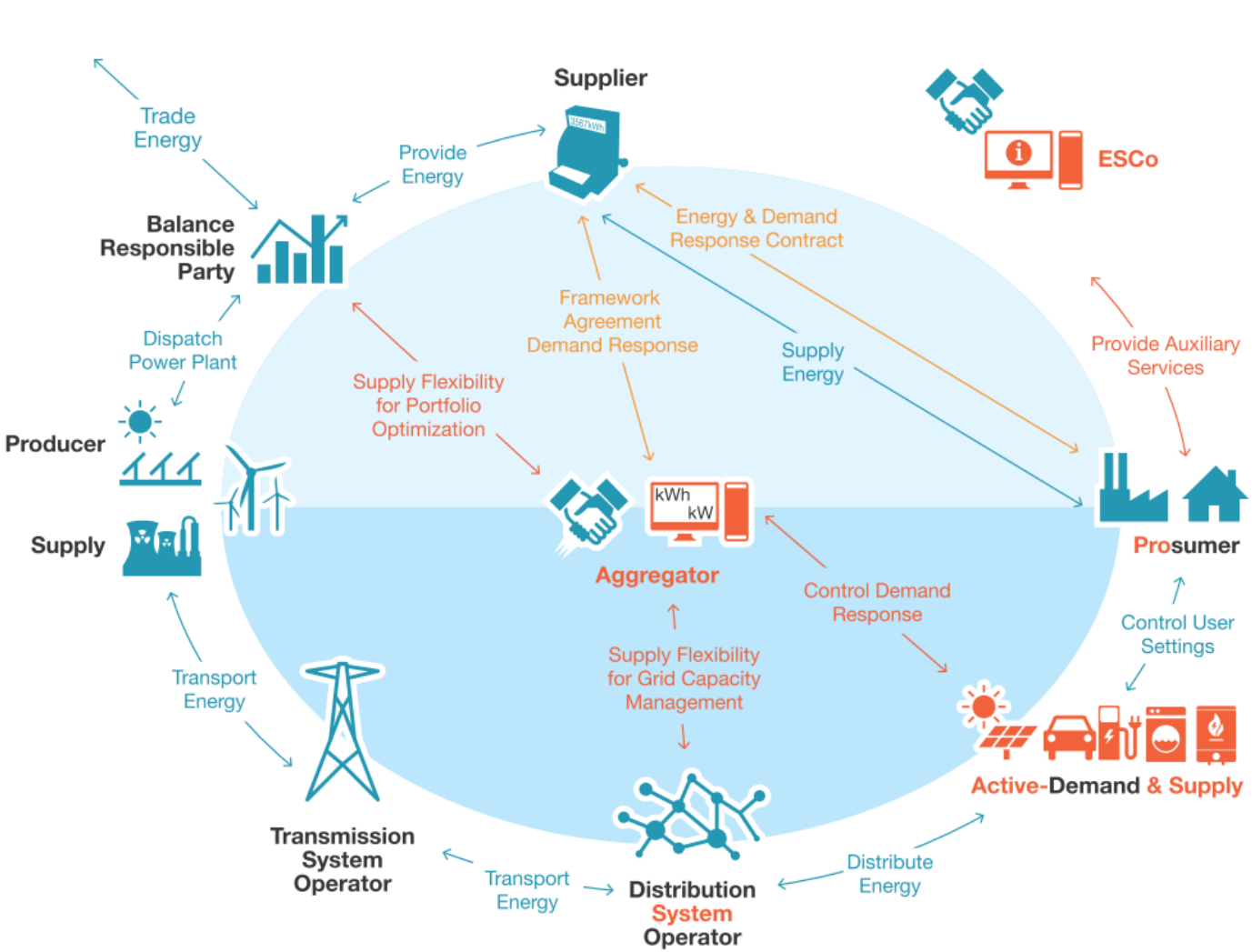
Smart Grid – A Cyber-Physical System

RES & Smart Grids



RES & Smart Grids

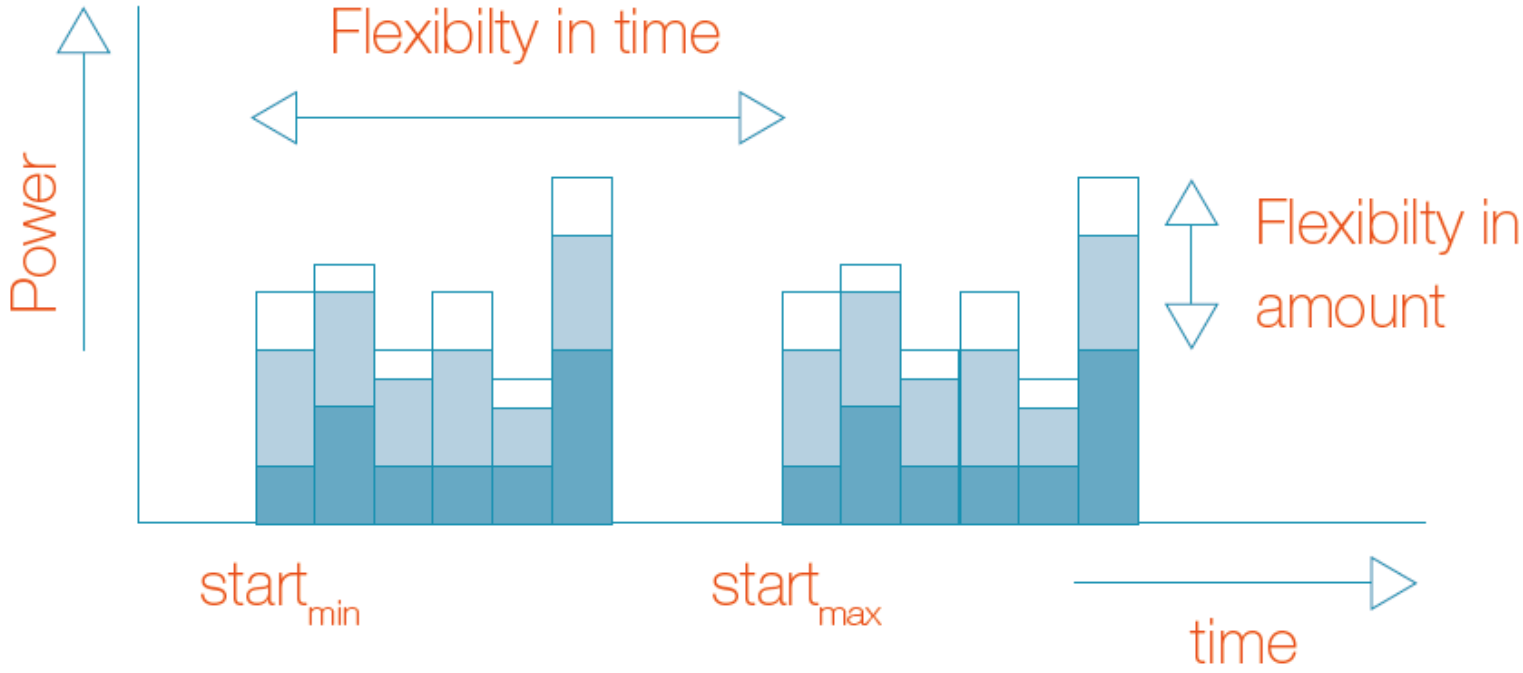
- … becoming quite complex Smart Grids



RES & Smart Grids

- **Demand Response: Flexibility vs. Uncertainty**

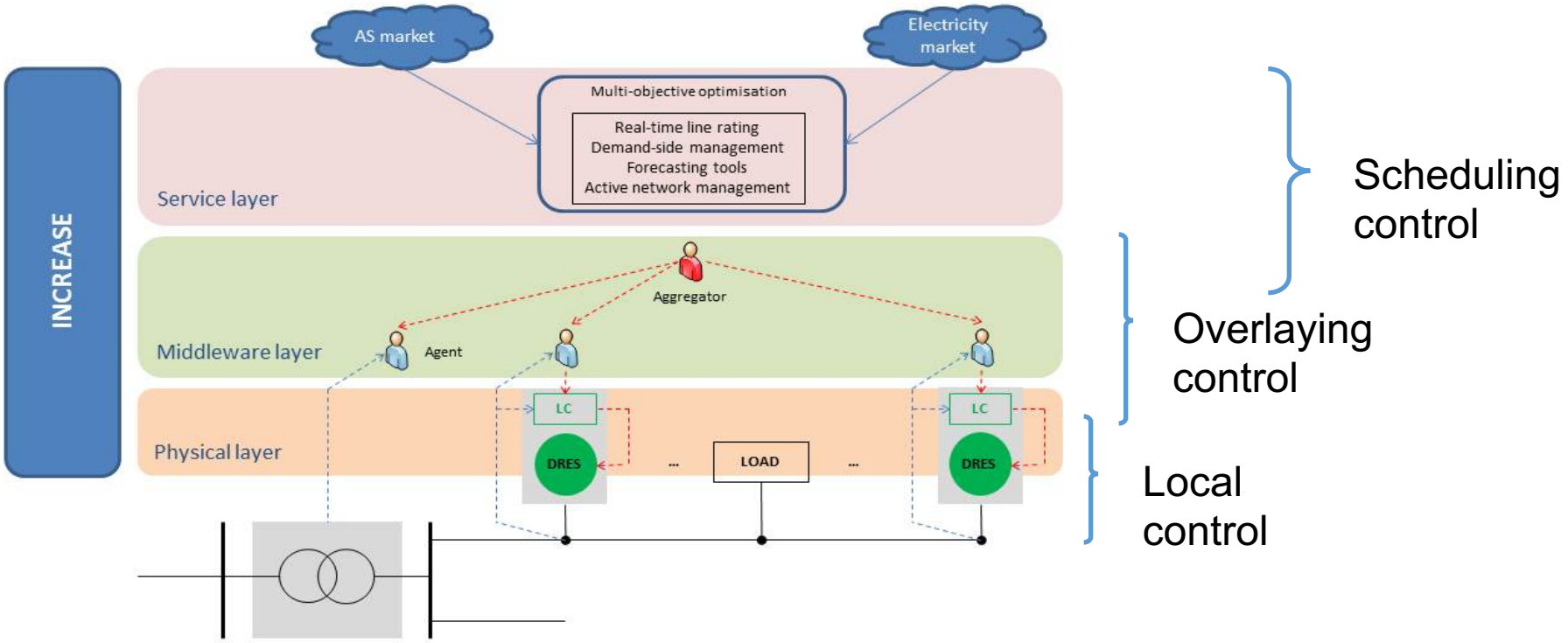
USEF Specification 2014:I



FP7 – INCREASE project

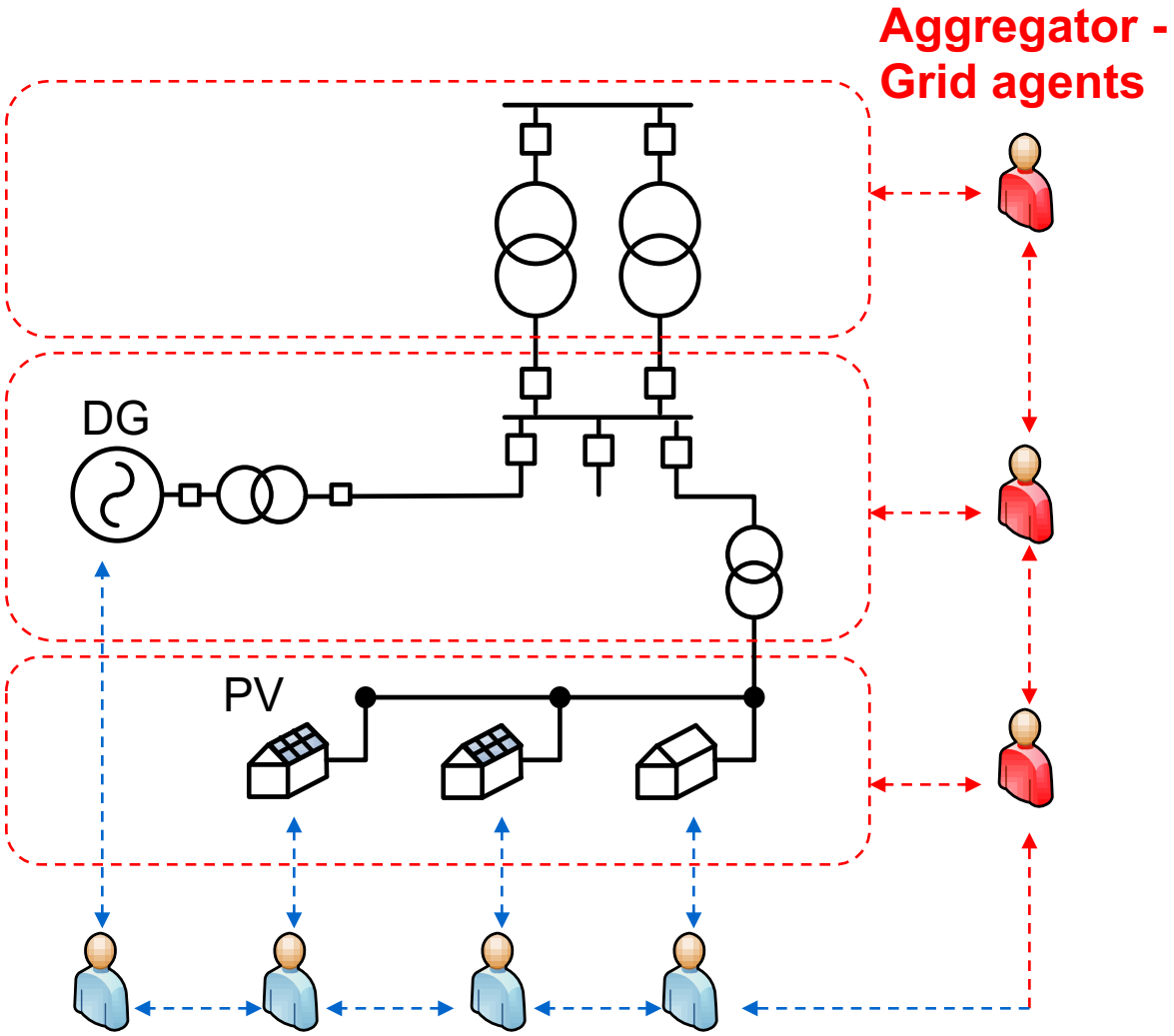
- 13 partners – 4 different countries
- Request EC budget: € 3M
- Duration: Sept. 2013 – Dec. 2016

INCREASE



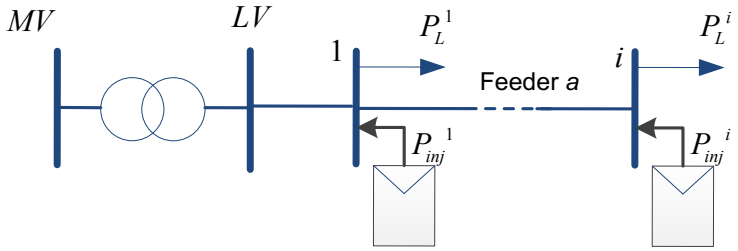
FP7 – INCREASE project

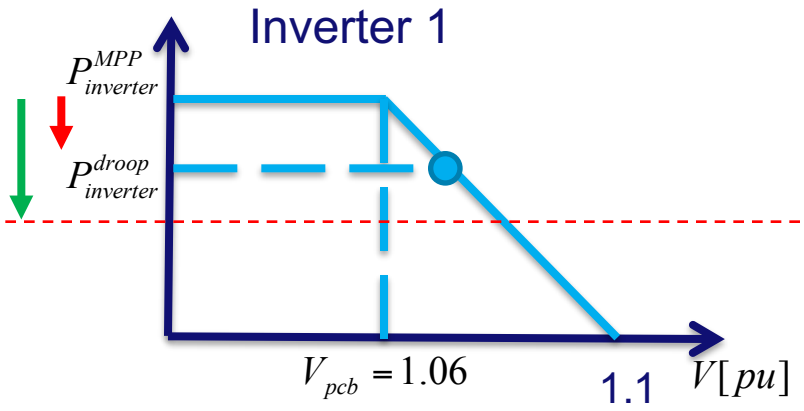
- **MAS features**
  - Scalability
  - Flexibility
  - Distribution
- **Benefits**
  - Complementary to SCADA
  - Complementary to the local control
  - Preventive behavior

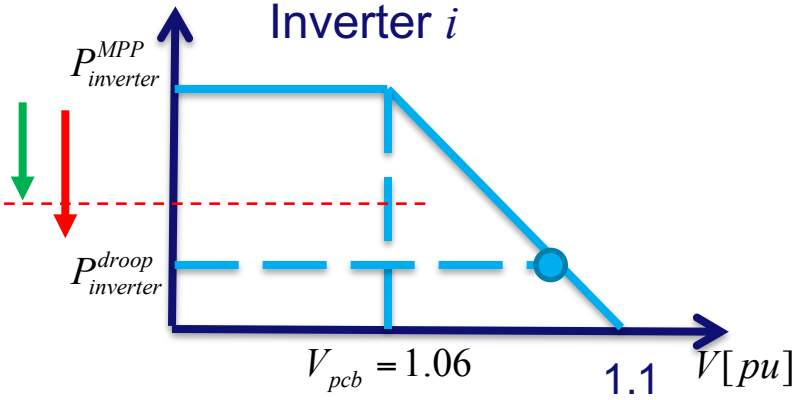


FP7 – INCREASE project

- **Problem formulation**



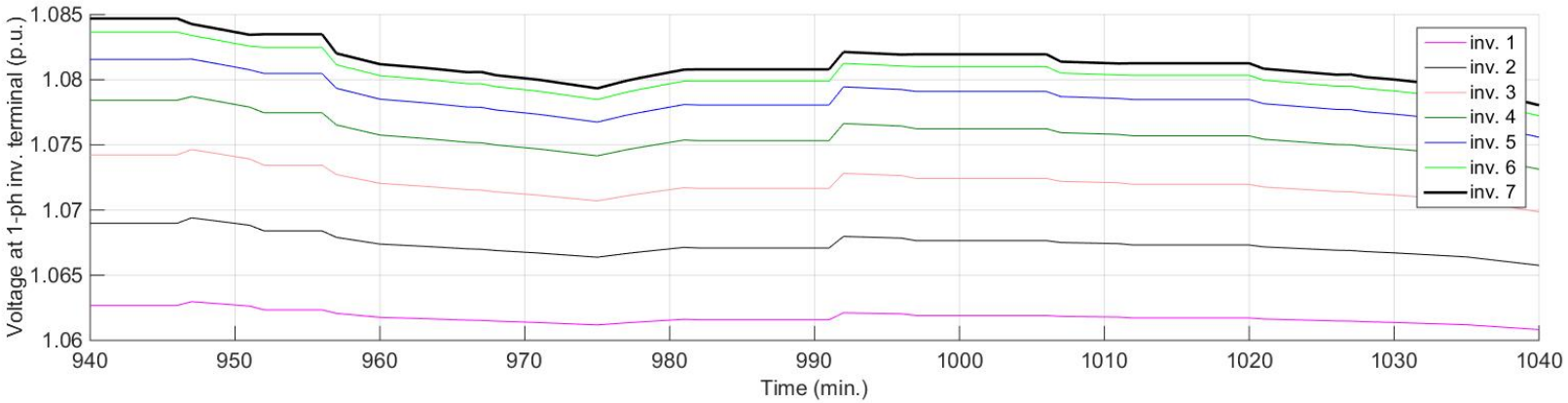


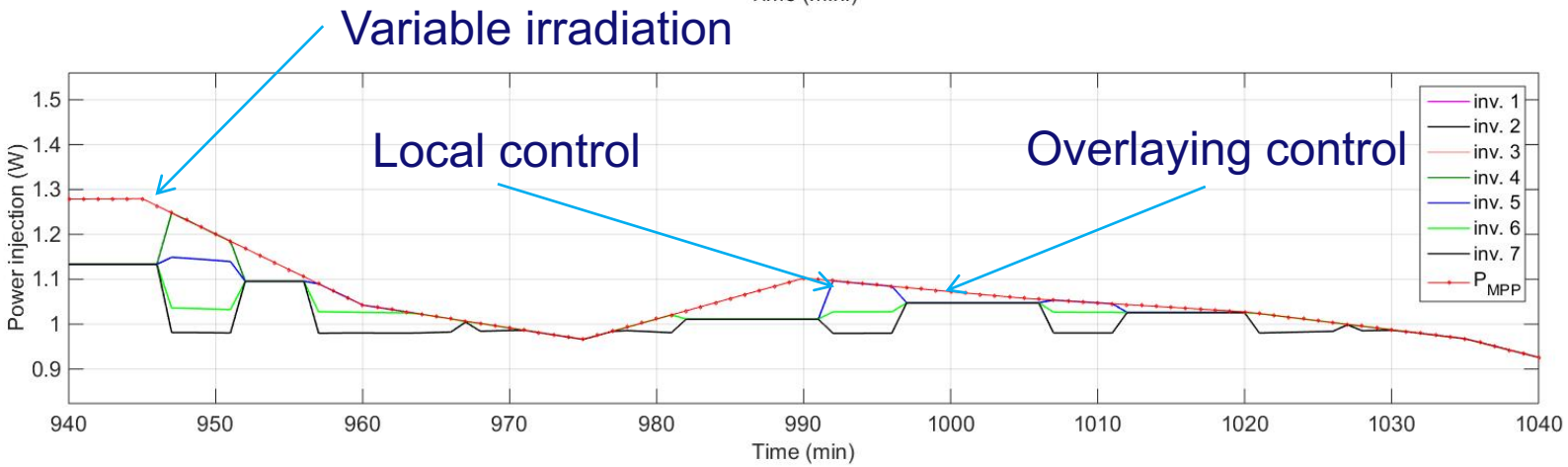


$$P_{curt}^1 \neq \cdots \neq P_{curt}^n, \leftrightarrow V_g^1 \neq \cdots \neq V_g^n, \in V_{cpb} < V_g^i \leq V_{max}$$

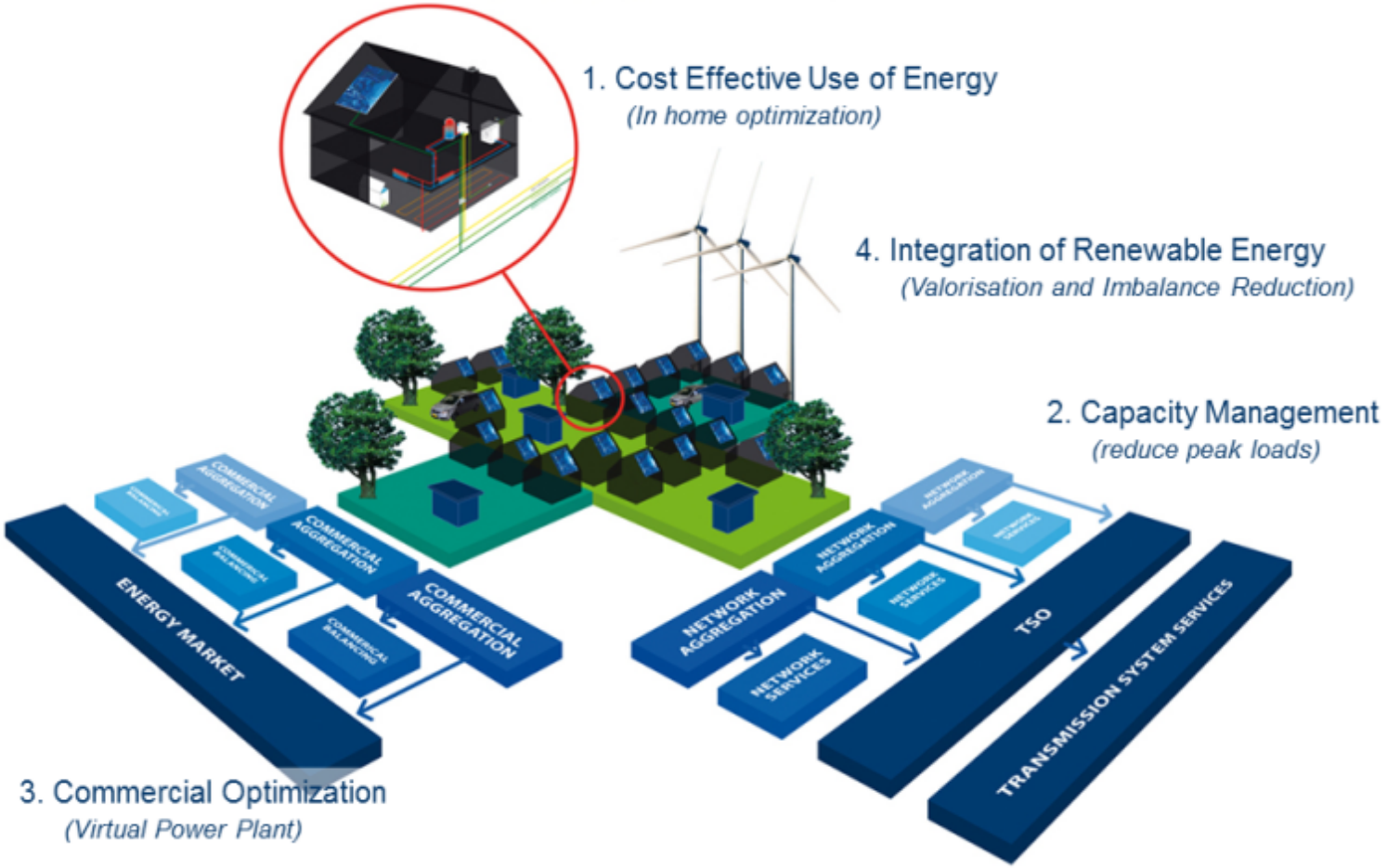
- Financial compensation?!
- **Technical control solution?!**

FP7 – INCREASE project

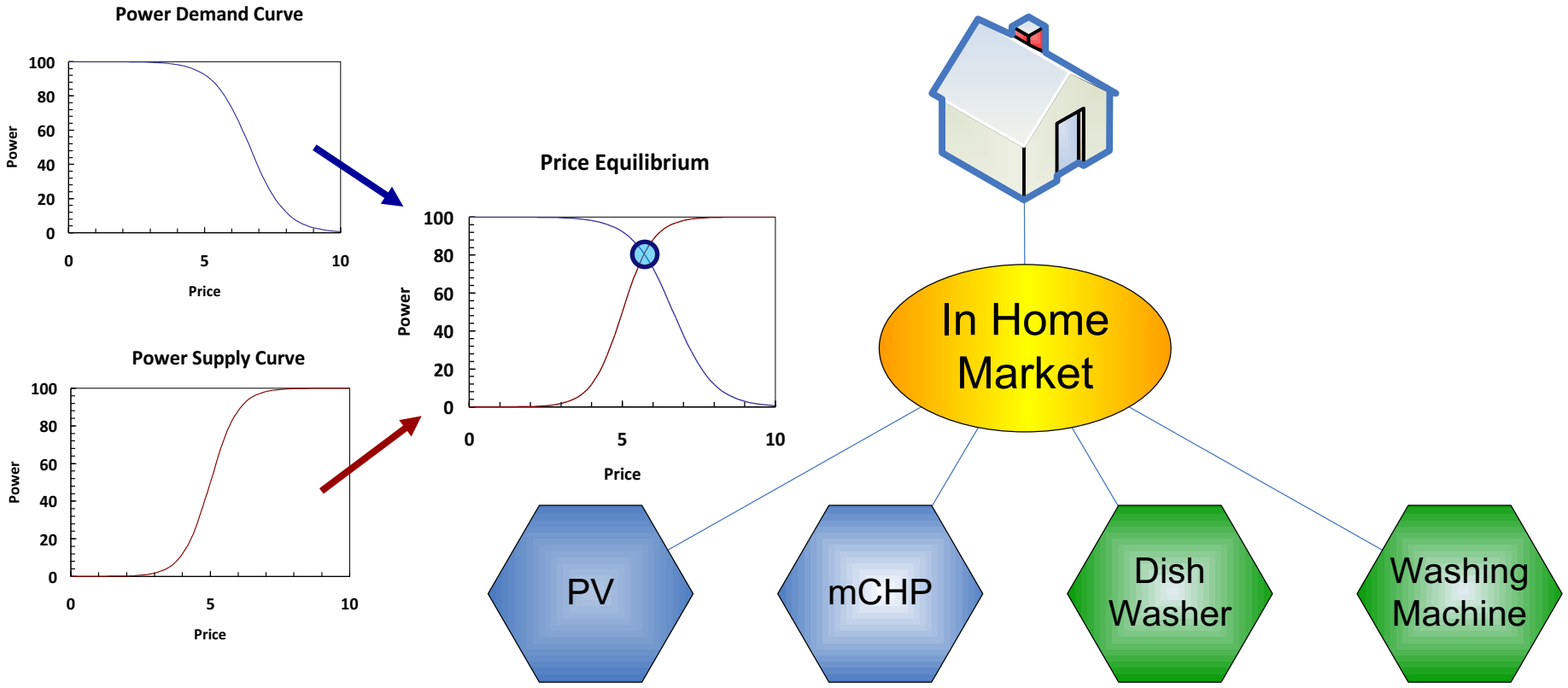




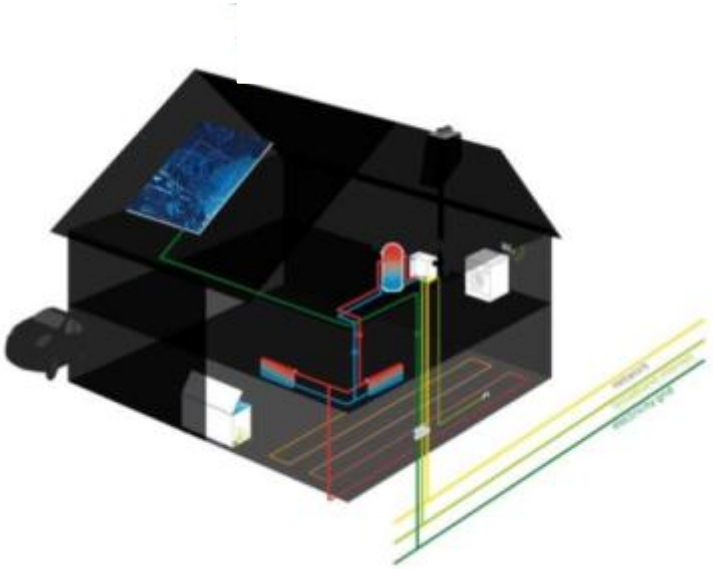
PowerMatching City II
Multi-objective Optimization

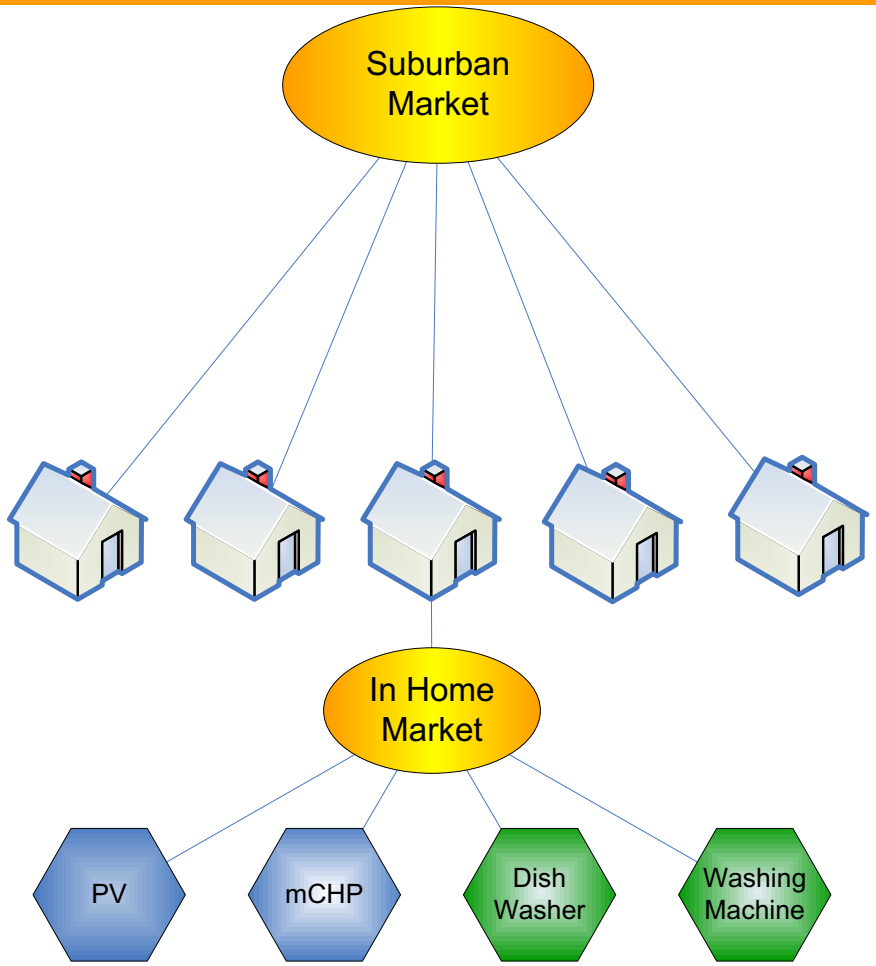


Energy Market in the Home



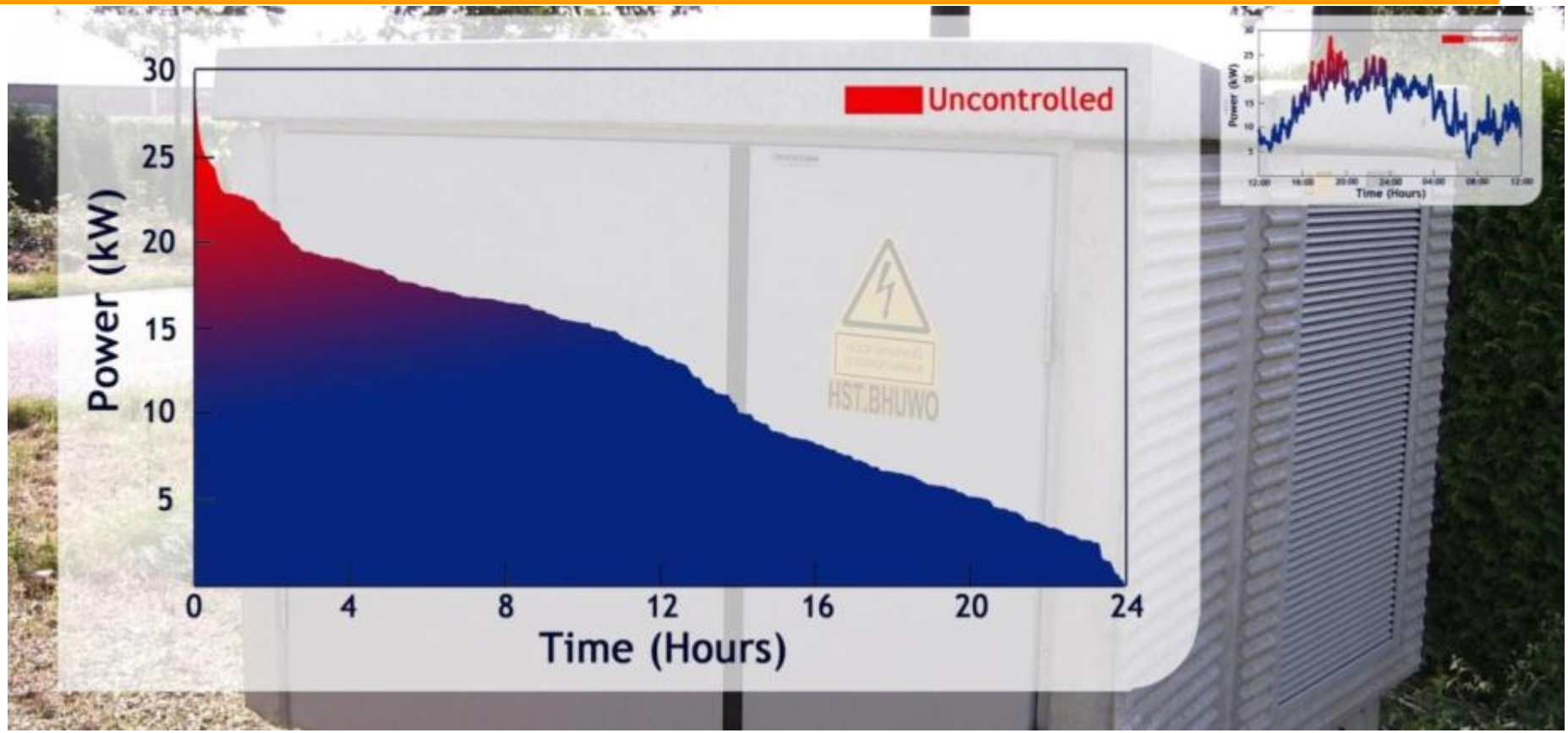
Local Aggregation in Suburban Market





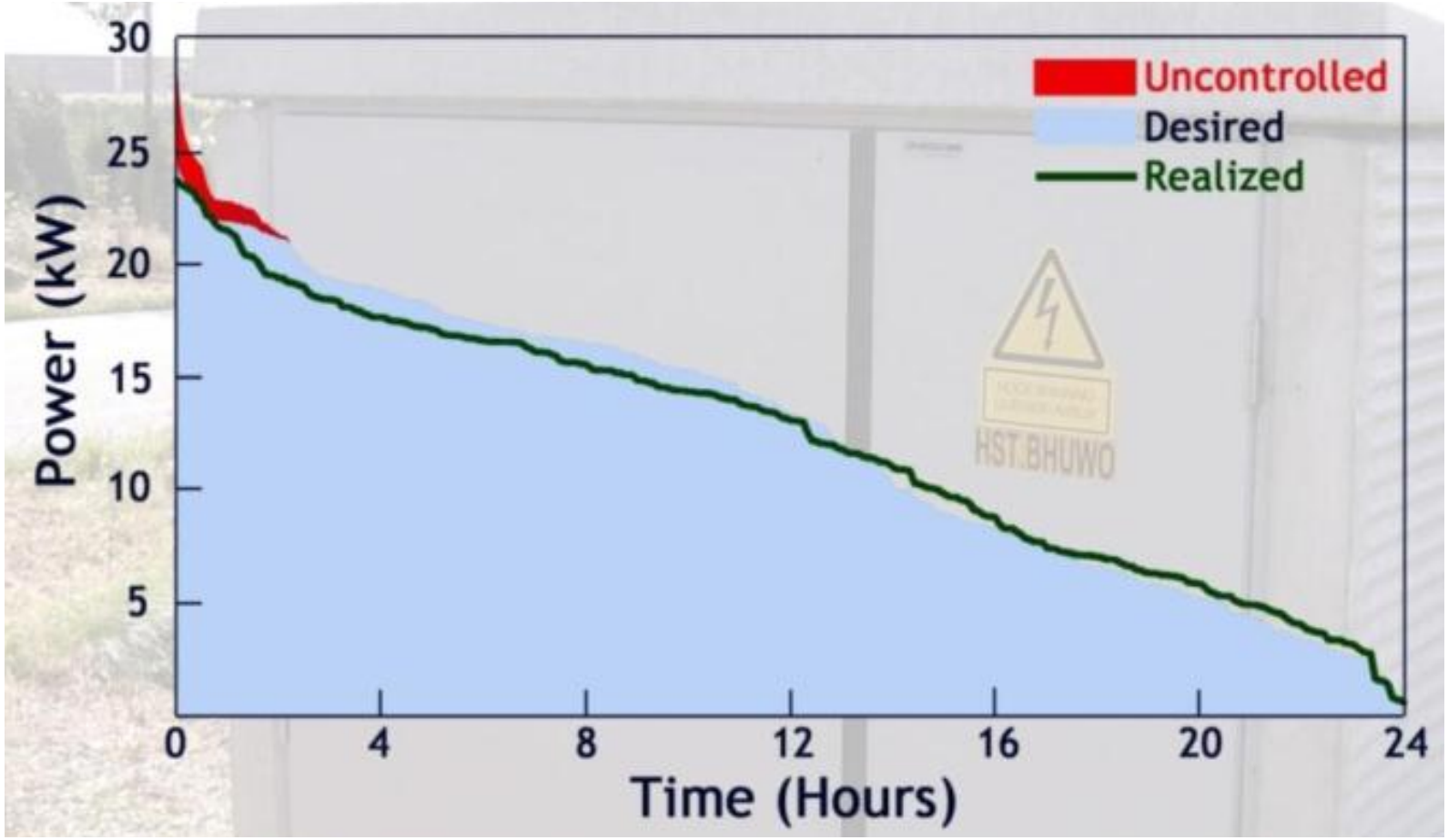
Central and Local Market Price

Uncontrolled Load Duration Curve
on a Distribution Station of a Virtual DSO



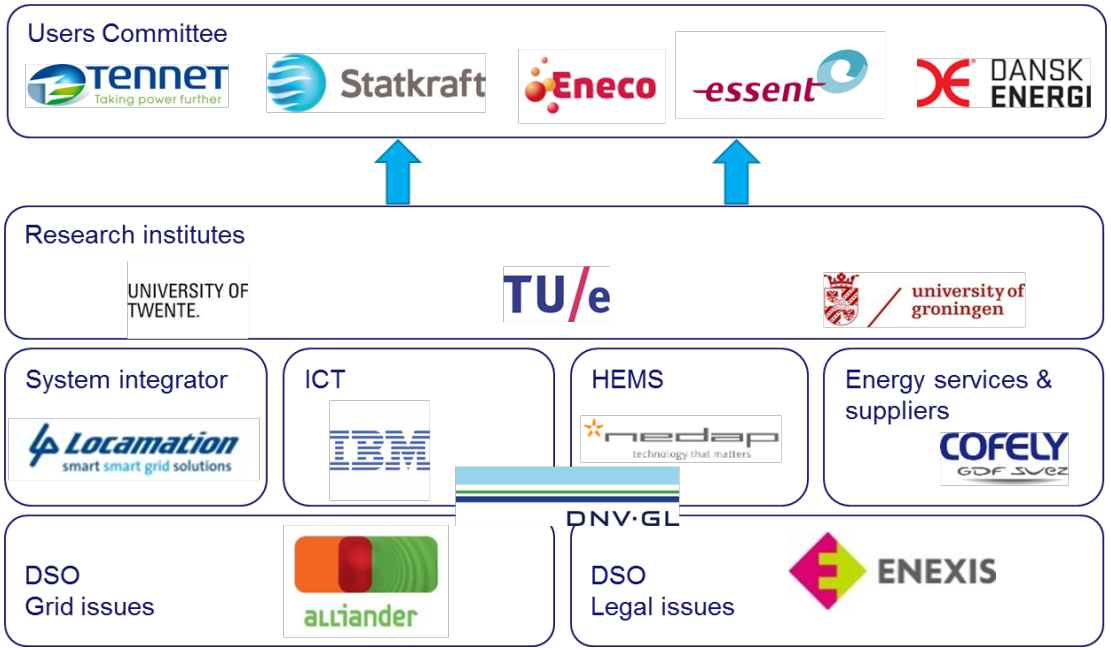
Assets must be sized based on peak power demand.

End Result – Desired Load Duration Curve via Active Capacity Management

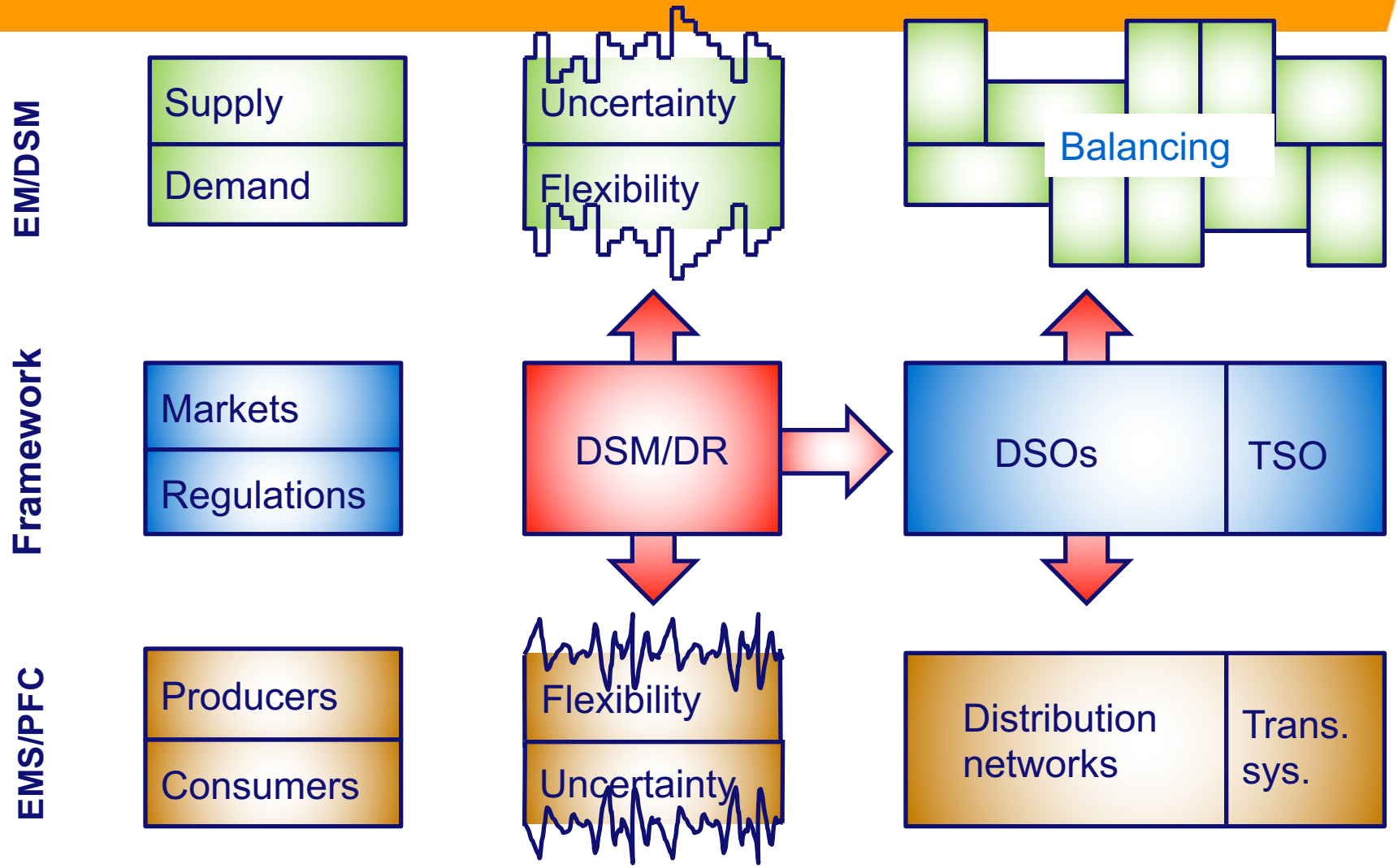


NWO project DISPATCH

- 3 academic & 10 industry partners
- Budget: € 1M (€ 700K subsidy)
- Duration: 2015 – 2018



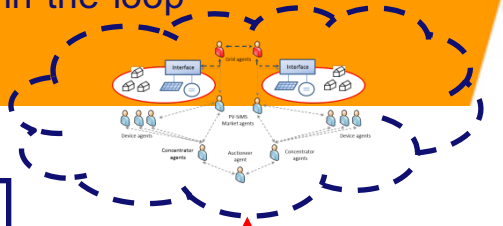
NWO project DISPATCH



EES lab

- 4 postdocs
- 9 PhDs
- 19 MSc students
- 2 visitors

Software-in-the-loop

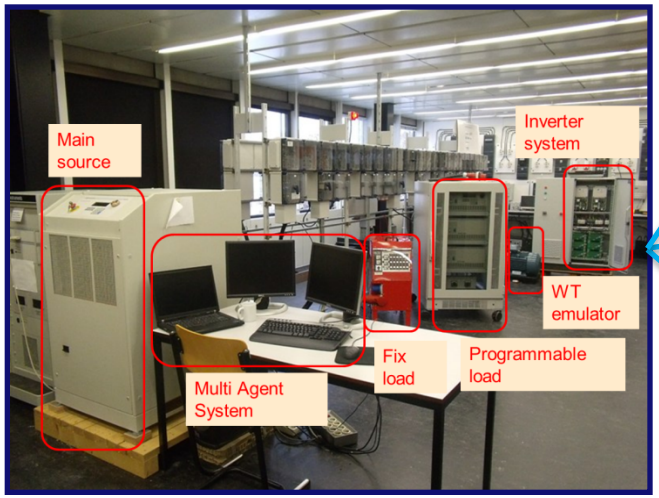


IPIN
ITSF

Power
Hardware-in-the-loop

NWO
DISPATCH

Real-Time Digital Simulator



FP7
INCREASE

Conclusion & Discussion

- **Smart Grids ~= Power Systems + Power Electronics + ICT**
- **Investment on grid infrastructure vs. ICT**
- **Centralized vs. Decentralized Control**
- **Flexibility from Demand Response can be an alternative**

Thank you!

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts